

Song Walker: Embodied Interaction Design for Harmony

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Tonal Harmony is widely considered to be the most technical and complex part of music theory, and harmonic skills can be hard to acquire. Experience of the precise and flexible manipulation of harmony in real time generally requires hard-won instrumental skill. Even with instrumental skills, it can be hard to gain clear insight into harmonic abstractions. The above state of affairs gives rise to substantial barriers not only for beginners but also for many musicians. To address these problems, Harmony Space [Holland et al, 2009] is an interactive digital music system designed to give insight into a wide range of musical tasks in tonal harmony ranging from performance and composition to analysis. Harmony Space employs a principled set of spatial mappings to offer fluid, precise, intuitive control of harmony. These mappings give rise to sensory-motor, music-theoretic and information-theoretic affordances that are not readily obtainable in any other way. The result is that a wide range of harmonic abstractions are rendered amenable to concrete, visible manipulation by simple spatial means. In the language of conceptual metaphor theory, most relationships in tonal harmony become accessible, to rapid, universal, low-level, robust human inference mechanisms using image schema, such as containment, contact, centre-periphery, and source-path-goal, in place of slow, abstract symbolic reasoning. While keeping the above principles invariant, different versions of Harmony Space have been designed to exploit different detailed interaction styles for different purposes. We note some key variants, such as the desktop version [Holland, 1994], the camera tracked version [Holland et al., 2009], and the most recent whole body version, Song Walker [Holland et al., 2011]. Preliminary results from a recent study of the Song Walker system are outlined, in which both beginners and expert musicians undertook a range of solo and collaborative musical tasks involving the performance, composition and analysis of music. Finally, we offer a discussion of the limitations of the current system, and outline directions for future work.

Whole-body interaction, Tonal harmony, Spatial metaphors for music cognition, Music computing

1. INTRODUCTION

The Victorian music educator Emil Dalcroze (1865-1950) noticed that his students showed little insight into musical rhythm if they lacked experience of enacting those rhythms with their own bodies. Dalcroze proposed that students needed to become competent in enacting representative rhythms with their bodies before they could achieve mastery of rhythm. Dalcroze's findings seem to be a special case of a more general phenomenon. Sensory motor contingency theory [O'Regan, K. and Noe, 2001; Holland et al, 2010] suggests that, in order to learn to organize and respond appropriately to sensory input in some new domain or context, it is typically an essential precursor that the individual learner's motor actions should have the power to affect relationships in the domain being sensed, so that the learner can repeatedly experience varied outcomes that they have themselves influenced. In situations where this very specific kind of feedback is absent, competency has been observed to fail to develop. This principle has been demonstrated in numerous different

contexts and time scales [O'Regan, K. and Noe, 2001].

We assert that a similar situation exists with musical harmony. Tonal Harmony is widely considered to be the most technical and complex part of music theory. Harmony skills are generally difficult to acquire, and are usually taught via symbolic notation. Explicit understanding of harmony involves knowledge of numerous abstract entities, categories and relationships, which are associated with an extensive specialised vocabulary. We assert that students show little insight into musical harmony if they lack experience of enacting and manipulating those harmonies with their own bodies – an experience which is scanty or non-existent for many students, but which can be achieved readily in ways that we will explore shortly. As with rhythms, simply hearing harmonies repeatedly, or studying them on paper, does not appear to be an adequate preparation for insightful skill.

The conventional way to enact full musical harmony with one's body is by playing a polyphonic musical instrument. Learning to play a conventional polyphonic instrument (e.g. a piano) competently typically takes months or years, thus, there are substantial barriers to achieving the prerequisites for mastery of harmony, not only for beginners but also for many musicians. But not even hard won polyphonic instrumental skills invariably lead to experience of flexibly manipulating harmony at will. For example, players who focus solely on playing from a written score typically cannot expect to develop the ability to manipulate harmonic sequences at will in real time.

A related point is that only a minority of musicians appear to gain working insight into larger scale harmonic abstractions. There exist many open-ended harmonic structures and strategies, some of which are generic, others which are specific to particular scales, tunings, idioms, composers, or pieces – yet few musicians gain develop mastery of manipulating such structures (i.e. composing or improvising well with harmonic materials). Reflecting on the achievements of musicians as diverse as Bach and the Beatles, both of whom manipulated harmony in highly original ways [Pedler, 2001]: to miss out on creative harmonic manipulation is arguably to miss out on one of the deepest joys of music.

In this paper we consider ways in which interaction design can be harnessed to help musicians, learners and beginners to gain experience in driving and manipulating harmonic sequences in real time, for the purposes outlined above.

2. THE SONG WALKER SYSTEM DESIGN

Harmony Space [Holland, 1989; 1994] is an interactive digital music representation system designed to give beginners and experts insight into a wide range of musical tasks ranging from performance and analysis to composition. When combined with whole-body interaction to create the Song Walker version [Holland et al., 2009], Harmony Space allows users to enact complex harmonic phenomena physically via mappings between a) bodily movement and b) conceptual metaphors and blends [Lakoff and Nunez, 2000] for musical abstractions. This approach affords rapid, concrete means of reasoning [Hurtienne and Blessing, 2007] about and manipulating abstract musical entities and relationships by exploiting intuitions associated with bodily movement and navigation.

2.1 Conceptual Metaphors

Harmony Space exploits a set of conceptual metaphors¹ that link concepts in tonal harmony to spatial concepts [Wilkie et al., 2010]:

Pitch

- Different musical intervals (octave, semitones, perfect fifths, major thirds, minor thirds) correspond to steps in different directions in space.
- In particular, semitones, fifths, and octaves are at right angles to each other in the plane, and octaves lie vertically (i.e., on the z-axis).

These conceptual metaphors employ extensions of Longuet-Higgins' (1962) and Balzano's theories (1980) of harmonic perception, which retrospectively may be seen as positing a three-dimensional image schema for tonal harmony.

Scales, keys and modes

- Common scales can be formed from the notes occurring in contiguous strips seven steps long in the fifths direction. Due to the repeating nature of the plane, these strips group into irregularly shaped two-dimensional areas (as illustrated in figure 5).
- Key areas are scales spatially situated to represent preferred territory for journeys and chord elements within the diatonic scale (see the white area in figure 5).
- A modal centre is a privileged location within preferred territory, typically where journeys start, end or rest.

Chords

- Chord qualities are oriented geometrical shapes. Preservation of chord quality requires retention of shape and orientation. Altering the pitch of a fixed quality is change of location of the shape without rotation.
- The most common chord qualities, major and minor, correspond to the most frequent three-element chord shapes formed by compaction within the geometry of the most common scales.

Harmonic movement

- Harmonic movement in terms of a chord sequence, is spatial trajectory.
- Composition is navigation, which may involve targets, directions, inertia, oscillatory movement and preferred territories.
- Tonal movement corresponds to trajectories along the diagonal from top right to bottom left or vice versa.
- Modal movement corresponds to trajectories along the diagonal from top left to bottom right or vice versa.

¹ Only the main types of metaphor are noted here, for a more elaborate discussion see Holland et al. (2011).

2.2 System Details and Interface

The Song Walker system employs whole body interaction through the use of four dance mats, four wireless controllers (wii remotes and nunchucks), various foot pedals, a large projection screen and a synthesizer. These are coordinated by a Harmony Space Server receiving data from controllers via HSp (Harmony Space protocol, a layer on top of OSC (Open Sound Control)).

When operated by a solo player, one dance mat is used to navigate a proxy for the player (represented by crosshairs in the wall projection) around in the projected space. Squeezing the trigger on the wii remote visibly and audibly plays the chord associated with the current location and situation. When operated by multiple players, additional dance mats may be used simultaneously in a variety of collaborative ways, for example, to navigate key changes or to harmonically invert or otherwise alter the chords.

The reason behind these interface choices is that we believe the current embodied interaction design offers affordances for more directly experiencing and enacting the conceptual metaphors in the domain than would be possible with a traditional desktop interface.

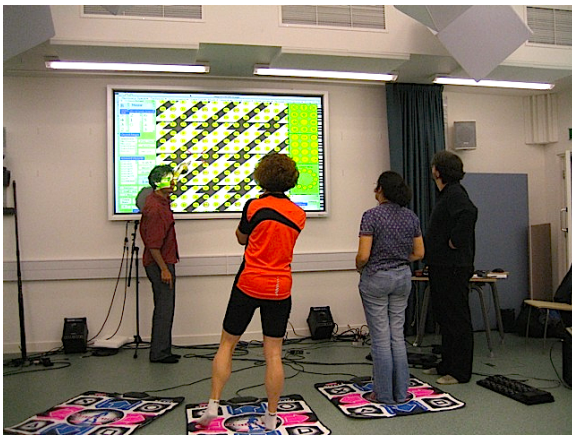


Figure 1: two players with asymmetrical roles.

2.3 Asymmetrical collaboration

As well as the potential advantages of whole body interaction for engaging with spatial phenomena, there are also potential advantages for supporting collaborative roles. Conventionally, when musicians collaborate to produce harmony, each musician contributes a single sounding part. From many purposes, this is highly appropriate. However, where players are novices, or where there is a desire to gain insights into the abstract structures of tonal harmony, one drawback of the conventional

approach is that that this process leaves these abstractions intangible and invisible.

By contrast, when Harmony Space is used collaboratively, the roles do not have to be split voice-wise, but may be split asymmetrically into heterogeneous spatial navigation and selection tasks, corresponding to abstractions of interest. Contrasting simultaneous asymmetrical roles available include the navigation of: the root path; changes of key; inversions and voicing; chord size; chord maps; altered chords; and bass lines. For particular pieces of music, typically only two or three of these roles are required at a time. The combinatorial interplay of these factors yields the detail of harmonic sequences. With multiple dance mats, players can readily see what other players are doing.



Figure 2: a solo activity, controlling Song Walker with dance mat and wiimote.

3. EVALUATION OF SONG WALKER

To explore the potential of the Song Walker system for learning about tonal harmony, an evaluation study has been carried out. The focus was on questions related to the embodied interface design, and issues related to collaborative learning.

3.1 Participants

16 people participated in the study. One participant did not fill in the questionnaire, so we present data of 15 participants - 8 women and 7 men, all adults aged 29-62, with an average of 36. Of these participants, 10 were experienced musicians (with five or more years of experience), and 5 were beginners (with zero or very little experience). Participants varied widely in their self-reported knowledge of harmony, covering the whole range

from absolute beginner (1) to expert (5), with an average of 2.7 on this scale of 1 to 5.

3.2 Setup

To support people in using the system in a collaborative manner, and to take advantage of the most important interface features, we developed specific musical tasks and instructions.

The participants were asked to carry out three different tasks with the Song Walker system, working in pairs, with task instructions projected on the wall next to the Harmony Space projection. The tasks included the following:

1. playing a chord sequence of a song
2. composing a new chord sequence
3. reharmonizing a chord sequence
4. analyzing chords and chord sequences
5. finding out about key tonality

All participants were assigned task 1, and at least two other tasks. The exact number and types of tasks assigned depended on musical experience, user interest, and time available. Each session lasted at least 45 min, with approximately equal time allotted to each task. Although we acknowledge that this implies that participants did not receive the same treatment, which may have affected the resulting experience, we believe the tasks had enough in common for all participants to get a good idea of the main functionality, interface, and conceptual basis of the system.



Figure 3: a three-player game.

3.3 Results

Playing a chord sequence of a song

After only a few minutes of training, all participants were able to play chord sequences of at least one well-known song to a recognizable degree (i.e., typically about 4-8 chords per song). Songs played included Ticket to Ride (The Beatles), Isn't She Lovely (Stevie Wonder), Pachelbel's Canon, Giant Steps (John Coltrane), and Billie Jean (Michael Jackson). Many people had to resort to a tempo

slower than the original song, though, and some had trouble with playing accidental wrong chords, especially in the beginning.

Participants were able to describe quite clearly what they had learned from this task, as the following quotes illustrate²:

"That harmonic structure can be realised in physical movements"

"That movements in chord sequences create very [definite] visual patterns"

Composing a new chord sequence

Regarding the open-ended collaborative composition task, all participants who received this task succeeded in creating a chord sequence that they felt sounded nice. Although part of the chord sequence was given, all pairs came up with unique chord sequence compositions. One pair of beginners spontaneously focused particularly on inversions and explored these carefully, with much discussion. Another pair of users deployed altered chords in a similarly careful way to musically positive effect. Participants noted that they had learned the following from this task, among other things:

"Using economy of movement to great effect."

"Mainly that you can create interesting chord (sequences) substitutions by thinking about what visual/spatial movements you want to make in Harmony Space (i.e. Diagonal vs. Vertical vs. Horizontal: each creating their own kind of substitution possibilities)"

One person had drawn several shapes (i.e., two triangles, and a triangle with a vertical line upwards) to illustrate spatial movement of chords that she had learned as sounding good.

This task seemed to offer opportunities for musical experimentation, as suggested by the following quotes:

"To try stuff out to see what works"

"Feeling free to really try and move from one chord to another"

"Experimentation!"

Reharmonizing a chord sequence

² Note: wherever participants' handwriting was hard to read, we have indicated our most likely interpretation in square brackets.

All participants who received this task were able to create variations on the chord sequence (a common harmonic sequence in jazz) given below:

||: Cmaj7 | Am7 | Dm7 | G7 :||

This resulted in many (20) different variations overall, and led to lively discussions among the participants about strategies for which chord to change and how to search for possible substitutions.

The participants mentioned having learned the following from this task, among other things:

"The combination of both the visual + auditory input helped me understand how chords relate to each other."

"The main point is that the spatial movements in the Harmony Space give me new metaphors, new ways of understanding relationships between chords"

"Chord sequences can be [composed] as paths in a grid [system]"

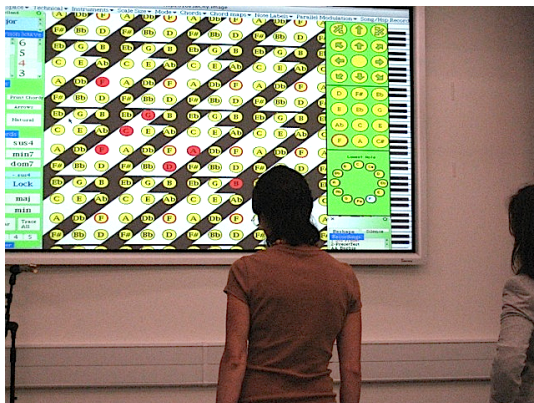


Figure 4: analysing David Bowie's Suffragette City.

Analyzing chords and chord sequences

Participants asked to harmonically analyse a piece, such as Suffragette City by David Bowie, were able to do so. This task required identifying the mode of the piece by physically shifting territory by means of a dance mat until the trace of the harmonic journey fell entirely within the preferred territory.

One participant noted the following learning effect for this task:

"Reminded me that songs can sound both major + minor if the chord sequences leave out the 3rd. (i.e. The main note that determines it as either major or minor)."

Finding out about key tonality

This task required identifying the mode of the piece by physically shifting territory by means of a dance mat until the trace of the harmonic journey fell entirely within the preferred territory (see figure 5).

About this task, one participant noted having learned the following:

"Can see puddles of sound much more easily - cluster chords."

General comments

Several users commented on the degree of physical engagement they brought to the tasks. To illustrate this, one initially skeptical user was able to learn to play the complete harmony of Pachelbel's canon after about ten minutes. At this point he said variously "I haven't got this musically in my head at all", "I don't have a sense of what's going on cognitively - how the visual representation is helping me remember it", and "visually overwhelming". However, about 30 minutes later, having played several more songs, he commented "Love the kinaesthetic quality" and "Once you're used to it, you could dance songs" (in the sense that Song Walker allows one to generate the harmony for a song by dancing to it).

Comments on the degree of physical engagement might be unremarkable in the case of, for example, arcade games, but are unusual in the context of tasks that are generally taught in knowledge intensive ways using rule-based, symbolic, and quasi-mathematical approaches. Also, conventional approaches to learning these tasks generally take one or two orders of magnitude longer.

Questionnaire

To find out if people's views on harmony changed after interacting with the Song Walker system, the questionnaire included the following question:

Before/After the experiment, did you consider the concept of harmony to be ... theoretical, practical, abstract, spatial, relating to physical movement, entertaining, dry, visual? (tick all that apply)

Compared to before the experiment, after the experiment, 8 more people associated harmony with 'relating to physical movement', 7 with 'spatial', 5 with 'visual', and 4 with 'entertaining'.

To find out to what extent people liked the various tasks, we asked:

How much did you like the task of ... using Harmony Space Song Walker?

1: I disliked it very much, 2: I disliked it a little, 3: I feel neutral about it, 4: I liked it a little, 5: I liked it very much

This question was asked for the five different activities. The results are shown below per activity:

1. playing a chord sequence of a song

(Mean = 4.64, SD = 0.50)

2. composing a new chord sequence

(Mean = 4.60, SD = 0.63)

3. reharmonizing a chord sequence

(Mean = 4.43, SD = 0.65)

4. analyzing chords and chord sequences

(Mean = 4.14, SD = 0.90)

5. finding out about key tonality

(Mean = 4.40, SD = 0.55)

This shows that the participants liked all tasks more than a little, on average, with the first two tasks scoring highest, and analyzing chords and chord sequences scoring lowest.

Interestingly, the scores for how much they had liked a task were positively related to how much they felt they had learned from the task.



Figure 5: performing the Beatles' "Ticket To Ride".

With respect to the interface, we asked how comfortable was it to use the interface. Participants scored a little above neutral, on average, although there was much variation for this question (Mean = 3.13, SD = 1.19, on the following scale: 1: very uncomfortable, 2: a little uncomfortable, 3: neutral, 4: reasonably comfortable, 5: very comfortable). They responded that the feeling of comfort generally became a little better during the experiment.

They felt that the dance mat interface was a reasonably usable way to move around, change key, and play bass notes in Harmony Space, and they felt that the wiimote interface was a more than reasonable way to carry out actions and make settings.

On the other hand, participants encountered several problems interacting with the dance mat, as indicated by reported issues related to keeping balance, overshooting due to the small size of the mat, changing feet, accidental presses, not being able to move fast enough to move smoothly, the mat becoming buckled up, and (sometimes) jumping notes or no response to the tapping.

With respect to the wiimote and nunchuck, most participants did not encounter problems, except one, reporting on oversensitivity of the joystick.

The participants reported thinking this technology helped them in their understanding of harmony (Mean = 2.23, SD = 0.44, on a scale of 1: Not at all; 2: A little; 3: A lot).

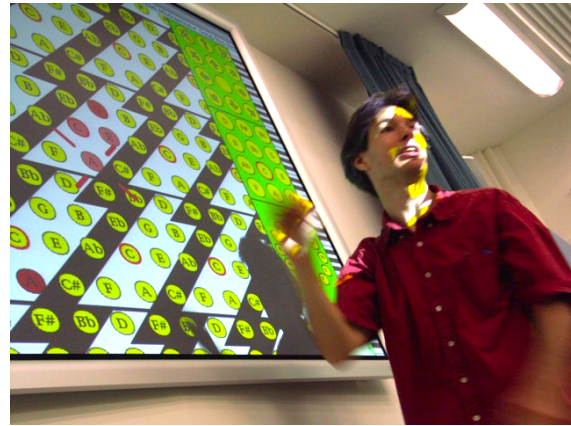


Figure 6: an Aeolian I minor seventh chord voiced in third inversion with a modal pedal.

Participants' suggestions for improving the system included the following, indicating individual differences in preference for the interface modalities:

- adding a metronome (at a slow tempo)
- for a beginner, hide complexity
- increase the size (of the mat)
- enable people to interact directly with the representation, e.g., using a tabletop
- move as much functionality as possible to the wiimote and nunchuck
- move more functionality to the mat
- improve the visualization of 'where you are'
- use the keyboard to the right of the screen to display chord inversions

Thirteen out of the fifteen participants enjoyed the experiment very much (the maximum score of 5), with two participants scoring 4 (I liked it a little). (4.87 on average, SD = 0.35).

WORK IN PROGRESS

In order to further explore how experience of physically enacting and manipulating harmony can be linked to the appropriate conceptual metaphors, we are developing versions of Harmony Space that will employ gesture-tracking devices such as Microsoft Kinect. Although frame rate and resolution are limited, the Kinect offers a useful complement to the architectural scale of the camera tracked Harmony Space system (Holland

et al, 2009) and the detailed expressivity of Song Walker, while offering improved portability.

4. CONCLUSIONS AND FUTURE WORK

Implications of this work relate to workshop themes in a variety of ways. Firstly, Song Walker Harmony Space offers a useful case study in extended uses of conceptual metaphor in interface design [Hurtienne et al; 2007, 2008] that is applicable to mainstream interaction design. This is noteworthy because the design makes extensive use of conceptual metaphorical blending [Lakoff and Nunez, 2000] which has been neglected as an explicit tool for interaction design. Secondly, the work provides a case study of a family of tools for a complex symbolic domain where the tools are able to transform symbolic entities, relationships and rules into relatively simple spatial tasks amenable to low level spatial inference [Bird et al, 2008]. Other case studies exist in other domains, but the present example is notable because of the highly complex, layered and abstract nature of the domain. Thirdly, the work is suggestive of ways in which whole body interaction can help users to operationalize spatial intuitions for domains that have been so transformed, in ways that may be less clear when interaction is via a desktop interface.

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